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DESIGN AND CUSTOMIZATION OF EMBEDDED BASED DIRECT TORQUE CONTROLLER OFINDUCTION MOTOR (DTC-IM)

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ABSTRACT

In the field of Electrical, DTC-IM plays vital role to control the torque. As a step ahead, in this paper we attempted to do research based on PIC microcontroller based PWM inverter controlled four switch 3φ inverter (FSTPI) fed IM drive. The advantage of this inverter that uses of 4 switches instead of conventional 6 switches is lesser switching losses, lower electromagnetic interference (EMI), less complexity of control algorithms and reduced interface circuits. Simulation and experimental work are carried out and results presented to demonstrate the feasibility of the proposed approach. Simulation is carried out using MATLAB SIMULINK and in the experimental work a prototype model is built to verify the simulation results.PIC microcontroller (PIC 16F877A) is used to generate the PWM pulses for FSTPI to drive the 0.5 hp 3-φ Induction Motor.

KEYWORDS: Induction Motor, Inverter, Lab Centre Software, PIC Microcontroller and Rectifier

INTRODUCTION

Direct torque control has many promising features and advantages such as absence of speed and position sensors, absence of coordinate transformation, reduced number of controllers and minimal torque response time. In addition, there are many limitations that need to be investigated. A major concern in direct torque control of induction motor drives is torque and flux ripples, since none of the inverter switching vectors is able to generate the exact stator voltage required to produce the desired changes in torque and flux. Possible solutions involve the use of high switching frequency or alternative inverter topologies. Increased switching frequency is desirable since it reduces the harmonic content of the stator currents, and reduces torque ripple. However, high switching frequency results in significantly increased switching losses leading to reduced efficiency and increased stress on the inverter semiconductor devices. Furthermore, in the case of high switching frequency, a fast processor is required since the control processing time becomes small. When an alternative inverter topology is used it is possible to use an increased number of switches, but this also increases the cost. However, if instead of applying a voltage vector for the entire switching period, it is applied for a portion of the switchin g period, then the ripple can be reduced. This is defined as duty ratio control in which the ratio of the portion of the switching period for which a non-zero voltage vector is applied to the complete switching period is known as the duty ratio.

DUTY RATIO CONTROL

In the conventional DTC a voltage vector is applied for the entire switching period, and this causes the stator current and electromagnetic torque to increase over the whole switching period. Thus for small errors, the electromagnetic torque exceeds its reference value early during the switching period, and continues to increase, causing a high torque

ripple. This is then followed by switching cycles in which the zero switching vectors are applied in order to reduce the electromagnetic torque to its reference value. The ripple in the torque and flux can be reduced by applying the selected inverter vector not for the entire switching period, as in the conventional DTC induction motor drive, but only for part of the switching period.

To examine the performance of the duty ratio controller the simulation was run at switching frequency 5 kHz. The difference between the conventional DTC and DTC with the duty ratio fuzzy control is clearly realized by examining the switching behavior of the stator voltage and the electric torque. Figure 1 contains voltage and torque switching in conventional DTC, where the drive output is updated at a rate of 5 kHz. The dotted vertical lines mark the beginnings of the sampling periods. It can be seen that the selected voltage vector is applied for the complete sampling period and the torque keeps increasing for the complete period; then a zero voltage is applied and the torque keeps decreasing for the complete sampling period and this results in high torque ripple.

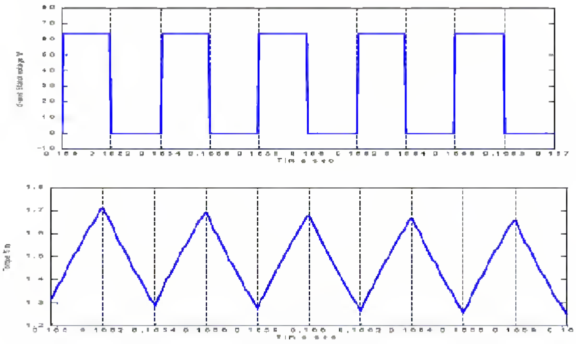


Figure 1: Voltage and Torque Switching in Conventional DTC

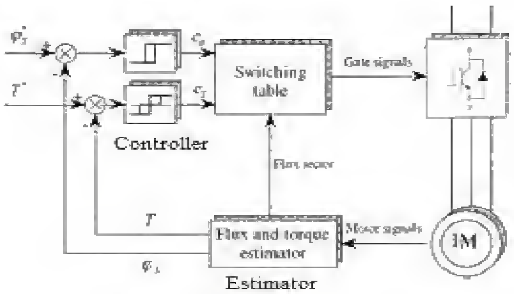


Figure 2: Direct Torque Control Scheme

Figure 2 shows a DTC of an induction motor. In direct torque controlled induction motor drives, it is possible to control directly the stator flux linkage and the electromagnetic torque by the selection of an optimum inverter switching state. The selection of the switching state is made to restrict the flux and the torque errors within their respective hysteresis bands and to obtain the fastest torque response and highest efficiency at every instant. DTC is simpler than field-oriented control and less dependent on the motor model, since the stator resistance value is the only machine parameter used to estimate the stator flux.

DESIGNING OF THE SYSTEM HARDWARE

In the simulation and experimental work as shown in Figure 3 & Figure 4, the single phase half bridge rectifier converts AC power to DC. The DC power is fed to FSTPI. The FSTPI converts the DC power to controlled 3-phase AC

power. The 3-phase induction motor is driven by the FSTPI. PIC microcontroller 16f877A is used to generate the controlled PWM pulse for FSTPI. The controlled PWM pulses of microcontroller are fed to the gate of MOSFETs of FSTPI through the driver circuit to drive the IM.

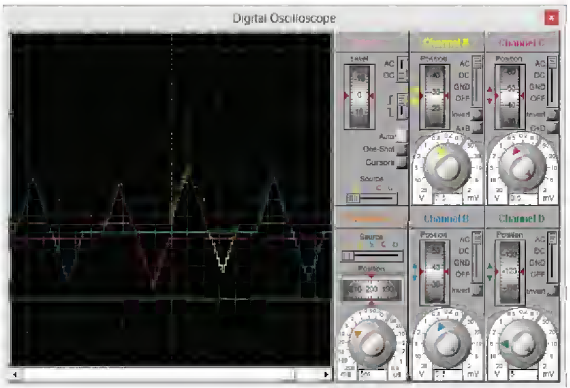


Figure 3: Simulation Results

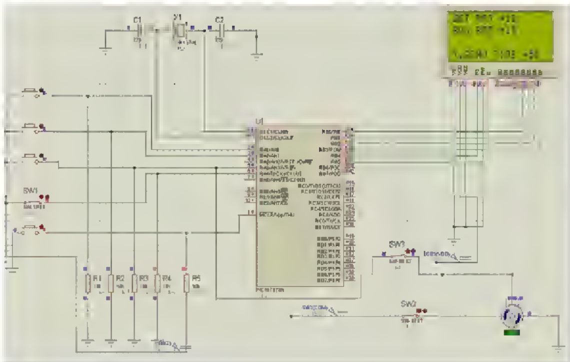


Figure 4: Simulation Results

PRINCIPLE OF FSTPI OPERATION

The power circuit of the FSTPI fed IM drive is shown in Figure 5. The circuit consists of 4-switches$S1$, S2, $S3$ and $S4$and split capacitors $C1$and $C2$. The 3-phase AC input, which is of fixed frequency, is rectified by the rectifier switches. The power circuit is the three-phase four-switch inverter. Two phases a' and 'b' are connected to the two legs of the inverter, while the third phase 'c' is connected to the center point of the dc-link capacitors, $C1$and $C2$.

The 4 power switches are denoted by the binary variables $S1$ to $S4$, where the binary '1' corresponds to an ON state and the binary '0' corresponds to an OFF state. The states of the upper switches (S1, $S2$) and lower switches (S3, $S4$) of a leg are complementary that is

$S3 = 1 - S1$ and $S4 = 1 - S2$. The terminal voltages Vas, Vbs and Vcs of a 3-phase Y-connected Induction Motor can be expressed as the function of the states of the upper switches as follows:

$$Vas=Vc3(4S1-2S2-1) \tag{1}$$

$$VcVbs=3Vc(-2S1+4S2-1) \tag{2}$$

$$Vcs=3(-2S1-2S2+2) \tag{3}$$

Where *Vas, Vbs, Vcs* are the inverter output voltages, *Vc* is the voltage across the dc link capacitors, (Vdc = *Vc*/2).

The complete prototype of the experimental setup and simulation diagram is shown in Figure 6. The details of the components used in this experiment are given in Table 1. The potential transformer is used to provide the power to PIC microcontroller board and driver circuit board. A single phase diode bridge rectifier and filter circuit is used to convert AC to DC. Four MOSFETs and 2-split capacitors are used to form FSTPI. The output of FSTPI is connected to the 0.5 hp 3-phase Induction Motor. Oscilloscope is used to display the PWM pulses and the output current waveform of *ia* .

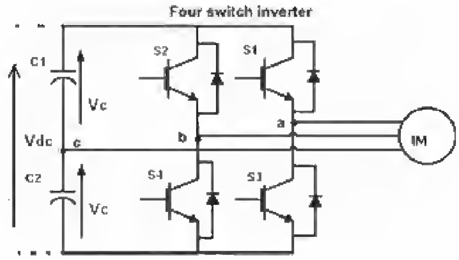


Figure 5: Four Switch Three Phase Inverter Circuit

Table 1: Shows the Different Modes of Operation and the Corresponding Output Phase Voltages of the Inverter

Switching States		Output Voltages		
S1	S2	Vas	Vbs	Vcs
0	0	-Vc/3	-Vc/3	2Vc/3
0	1	-Vc	Vc	0
1	0	Vc	-Vc	0
1	1	Vc/3	Vc/3	-2Vc/3

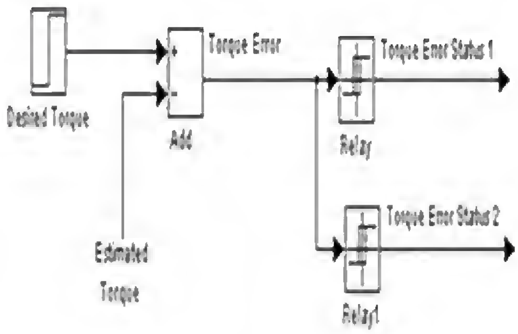
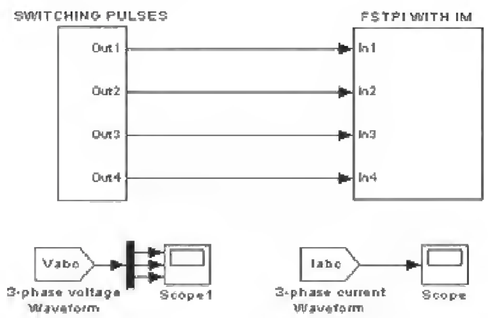


Figure 6: Simulink Block Diagram of FSTPI Fed Drive System



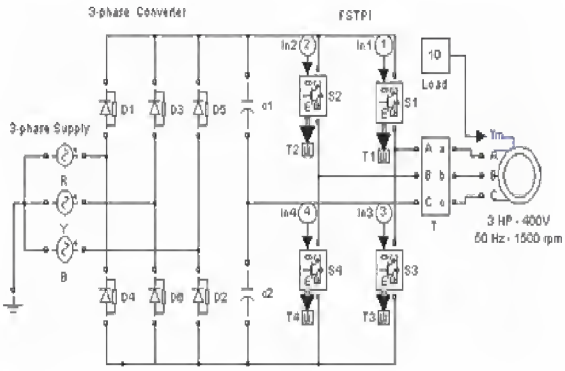


Figure 7: Complete Simulation Circuit Diagram of FSTPI Fed IM Drive System

SOFTWARE IMPLEMENTATION

In the experimental work, source code is written in the C language using MPLAB's inbuilt text editor. The source file is then compiled by invoking the PCB or PCM compiler in the MPLA B window. The code was tested using MPLAB's simulator. Finally the microcontroller is placed in the PICSTART programmer and programmed.

APPLICATION

Because of their robustness, cheapness, high speed operation and less maintenance requirements, the induction motors (IM) are the most common type of electromechanical drive in industrial, commercial and residential applications. To reach the best efficiency of induction motor drive (IMD), many new techniques of control have been developed in the last few years.

CONCLUSIONS

A PIC microcontroller based PWM controlled FSTPI fed Induction Motor drive has been designed and implemented successfully. The simulation and hardware implementation results are presented to verify the feasibility of the system. The implementation of the proposed work shows the practical industrial application FSTPI.

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